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A SBIR Phase I project was undertaken by Delta Data Systems, Inc. and Neptune Sciences, Inc. which focused on feasibility issues relating to the development of a Marine Geographic Information System (MGIS) that could support Logistics Over the Shore (LOTS) planning and operational monitoring tasks. Significant feasibility issues such as interfacing with wave models and ancillary data integration were addressed and resolved in the Phase I effort.

Phase I prototype MGIS proved that value added support to the LOTS is feasible and generates visualization of coastal environment and coastal processes from historical and contemporary (near real time) perspective. Phase I prototype proved geographic information organized in a spatial context sufficiently increases information quality and retrieval speed for supporting LOTS interactive decision making. The LOTS decision making is creditable since the decision making is a function of data availability and quality.

Phase I successfully demonstrated an interchange between the Navy SURF model and a prototype MGIS. The SURF model was "fed" by MGIS and SURF model output was visualized as a map of predicted wave activity in the prototype MGIS. Bathymetry, wind, tide, WDBII/DLG shoreline, and surface generation provided the input data that conceptualized an integrated MGIS.

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SBIR Final Report - GIS for Marine Operations

Executive Summary

An SBIR Phase I project was undertaken by Delta Data Systems, Inc. and Neptune Sciences, Inc. which focused on feasibility issues relating to the development of a Marine Geographic Information System (MGIS) that could support Logistics Over the Shore (LOTS) planning, operational monitoring and analysis tasks. Significant feasibility issues relating to MGIS-numerical model interaction were addressed in the Phase I effort.

Our view of MGIS support to LOTS involves visualization of the coastal environment and coastal processes from both an historical and a contemporary (near real-time) perspective. MGIS can organize information in a geospatial context. Making the context sufficiently "information rich" to support interactive decision making is a function of data availability and quality.

We believe that GIS is a mature technology that has established an ability to create, integrate, display and analyze georeferenced data in a visually informative system. However, applying GIS visualization and analysis to planning problems in the littoral environment poses challenges in data collection, data integration, visualization and mapping that are generally not encountered in land based GIS projects.

Unlike land based GIS development which (in several industrialized countries) is supported by ready access to a well developed, relatively high resolution, spatial data infrastructure, marine based GIS development must rely on comparatively under-developed, low resolution geophysical and meteorological data bases. In addition, the dynamic nature of the near shore and surf zone "landscape" requires that much of our view must be developed through modeling. Modeling relies on hindcasts, forecasts and/or near real time observations of sea state and weather conditions (in combination with physiographic data) to develop an estimate of their combined effect on (normally a very small) surface region near the coast including the surf zone.

The principal challenges in determining the feasibility of and planning the implementation of MGIS were:

1) Data collection and data integration.

Efficient and effective strategies must be designed to enable rapid location and integration of geophysical and meteorological data of two general types, historical and near real-time with different characteristics.

A survey of data sources and marine information systems was completed in Phase I. Navoceano's IDBMS, the Master Environmental Library and the Satellite Active Archive

were identified as examples of "area locator" information systems which represent new wave, internet-based tools. In addition, geoprocessing tools were applied to the development of high resolution surf zone bathymetry and shoreline as a demonstration of critical data development in cases where no digital data are available.

2) Integration of numerical modeling with GIS.

A workable exchange between selected numerical models and MGIS must be developed. The specific concerns are how to use geoprocessing tools to "feed" environmental and geophysical data to models and how to integrate and visualize model output in a geographic context for application to LOTS planning and operations.

As an example, Phase I successfully demonstrated an interchange between the Navy surf model and a conceptual MGIS. The surf model was "fed" by MGIS and surf model output was visualized as a map of predicted wave and surf conditions.

3) Human Factors.

A task oriented, graphical user interface must be created that effectively supports varying levels of user background and expertise.

The development of a conceptual MGIS in Phase I provided insight into task identification. Basic software design concepts for a Phase II implementation were developed. A concept MGIS was developed and delivered to the SBIR Technical monitor at WES that included data and representative geoprocessing tools.

Project Overview: Objectives and Results

Objectives:

1. To identify technical feasibility issues relating to the integration of geoprocessing and numerical modeling to support LOTS planning and operations. Specific focus was on MGIS-numerical model interaction. To demonstrate an exchange of data and information between a geoprocessor and a numerical model, we developed a test which would generate and then visualize a surf zone forecast in a detailed geographic context. (Although several models were identified, the Navy SURF model was the only surf forecasting software available for operation during Phase I.)

2. To investigate sources of geophysical, oceanographic and meteorological data in digital form and to assess their accessibility and utility to a LOTS planning and decision support package. Again, the primary focus was on data related to the requirements of a surf forecasting model. Foremost among these were bathymetry and observations of wave, wind and tide. This part of the effort was performed specifically to provide insights into LOTS planning and decision support design issues.

3. To test various "processing hypotheses" relating to data generation and visualization. Specifically, we were interested in the applicability and adaptability of an existing set of surface modeling and profiling tools to the generation of bathymetry and the extraction of numerical model input parameters.

4. To identify software and system design considerations for an extension of the work in a Phase II effort.

Results:

1. A general review of digital data sources was completed. This information was interpreted to provide Phase II guidance.

2. Experimentation with selected digital data sets led to a working demonstration of the production of near real time LOTS planning information for a selected area near Camp Le Jeune, NC. The data along with operational software were delivered to the SBIR technical monitor at USACE/WES.

3. "Processing hypotheses" were tested in a two-way exchange of geographically encoded information between a geoprocessor and a numerical (surf forecasting) model. We were able to demonstrate the development of high resolution bathymetry from multiple input sources using a surface building application. The bathymetry was then processed, in what we consider to be a typical MGIS-

numerical model interaction, into numerical model input. The numerical (surf) model was run and its output was imported into our conceptual MGIS for visualization.

4. We identified two general modes of MGIS operation as the basic design concept for Phase II :

   a) Climate Mode, in which knowledge of a LOTS area is developed as a general review of trends in an area's environmental processes (from wind, wave, surf, current and tide histories). The characteristic data for this mode are statistical reports and graphs;

   b) Forecast Mode, in which observations and analysis are made through visualization, geoprocessing and numerical model interaction in a detailed geospatial context.

Project Narrative

Our View of GIS Support to LOTS

A LOTS planner is concerned with moving material and people from sea to shore using transports and assets whose capabilities are affected by environmental conditions. Much of the LOTS planning problem focuses on gaging vessel and asset capabilities relative to conditions predicted for many types of environmental conditions, particularly waves, surf, currents, tides and winds. Other types of information such as water temperature, air temperature and bottom characteristics my also be important. Bathymetry is of key interest because depth variations have a strong affect on wave refraction and surf characteristics.

We know that GIS can be used to present a georeferenced view of an area of operations as a collection of thematic maps. A thematic map can represent anything- a detailed shoreline, bathymetric contours, predicted wave activity, the mapped positions of submerged or shore-based structures, etc. In our current GIS design, there are no effective limitations as to the number or content of thematic components. The only requirement is that all components have been transformed (geometrically and geographically) to a common projection.

A series of standard geoprocessing functions can be invoked to allow an operator to "navigate" the GIS- changing viewing opportunities by theme or scale, calculating distances and bearings from point to point or initiating queries based on location or (thematic) attributes.

At a general level, GIS is a tool that can already provide a substantial assist to LOTS planning and decision support by visualizing the changing features of the nearshore

environment- How is the shoreline oriented? Where are significant shorebased features? What are the observed (mapped) hydrologic and geologic features? We see no technical problems in producing a visual, geographic data base of this class of littoral zone data. The static and low dynamic thematic components of a MGIS can be developed from numerous digital and analog sources.

The question is how to augment a MGIS with processing capabilities from the predictive side of things- where maps based on numerical model output will provide a visualization of the highly dynamic littoral zone at times and scales selected by the planner.

MGIS - Numerical Model Interaction

A Phase I goal was to explore the processes through which static and low dynamic data could be located, acquired and integrated and through which the input requirements of a numerical forecast model could be developed. We selected the Navy surf model as a testbed.

Model Inputs

Bathymetry

Bathymetry is a critical element in many forecast models which MGIS is likely to interact. It is used in grid cell format to calculate wave refraction in near shore models (e.g. STWAVE) in profile format for surf zone calculations and surf statistics.

Sources of digital bathymetric data were determined to be well-established but varying widely in geographic coverage, scale and accuracy. From the civilian perspective, surf zone bathymetry, the data that would actually be required for surf zone forecasting, is largely non-existent, particularly in areas where LOTS exercises may occur. Military beach studies are the main source of very high resolution surf zone bathymetry at a reasonable number of locations.

Expanding GIS to include tools for building gridded bathymetry.

The critical importance of bathymetry requires that MGIS incorporate tools for building bathymetric maps. In Phase I, various methods of creating high resolution depth charts from digital and analog sources were identified and investigated.

The basic input to depth chart production is a geoencoded sounding- a longitude (or projected easting), a latitude (or projected northing) and an observation of depth. Data in this form is available in several digital data bases (e.g. NOS Hydrographic Data Base, Navy DBDB(n)). Data can also be produced in this form by digitizing nautical charts. Given the convergence of DGPS and sensor technology, very high resolution

data in this form may ultimately be developed in near real time by special forces operations before amphibious and LOTS operations.

SURFACE is a tool developed by DDS that can be used to generate gridded bathymetry from geoencoded sounding data. Its important operational aspects are:

1. Accepts delimited ASCII input.
2. Automatically transforms input projection and datum to a user defined "project" projection and datum.
3. Operates in an APPEND mode to allow multiple source inputs.
4. Permits interactive definition of spatial limits.
5. Offers a selection of linear or non-linear interpolation schemes (Trend Surface, Nearest Neighbor, Inverse Distance, Exponential Decay).
6. Produces output at a user defined spatial resolution. This feature is very useful in relation to models that require flexibility in defining input grid sizes. Wave refraction models are an example. The SURFACE tool can be used to efficiently build variable sized output grids from a single input source.

Figure (1) is an example of SURFACE output. The inputs were a combination of digitized extractions from a NOAA chart and digital STOIC chart soundings.

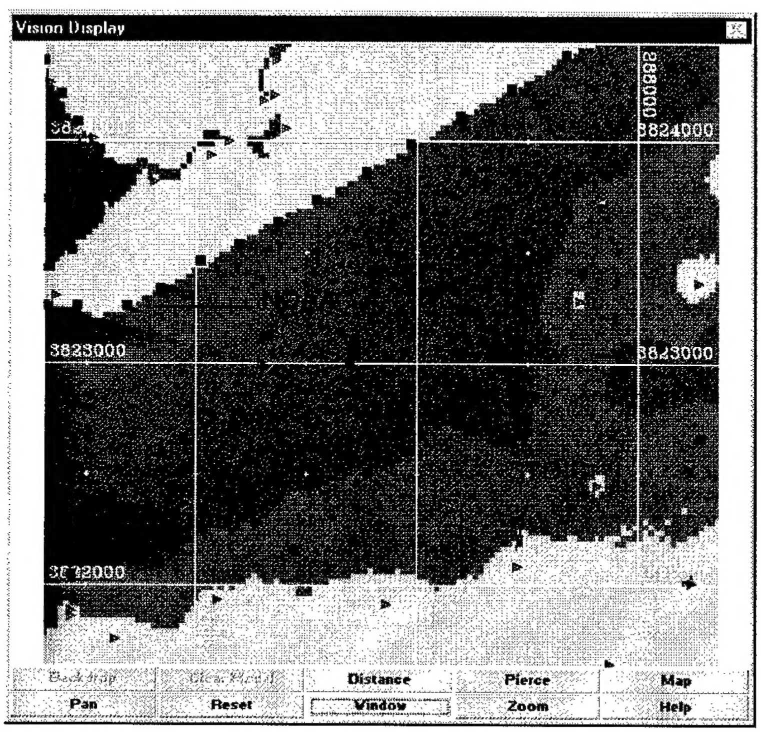


figure 1

The significance of this analysis is:

1. The product is a thematic component of a MGIS project.

2. The product is a geographically accurate visualization of depths at a high resolution.

3. The overall accuracy of the interpolated surface is defensible as a function of the accuracy and density of the input soundings. The interpolation algorithm effectively "honors the data."

4. The product is in a format that is compatible with near shore wave refraction models that require gridded bathymetry as input.

5. The source of the data is not critical. Geoencoded soundings can be accessed from existing data bases, extracted from nautical charts or collected from active sensors. The important operational factor is geography and data format. We also note that bathymetry can be progressively refined with successive data inputs.

6. The product was developed in a few minutes of processing time on a $3,000.00 Pentium PC.

The demonstration of the applicability of SURFACE to MGIS-numerical model interaction is considered important because it represents a capability that can be leveraged in Phase II development through a manageable work plan effort.

In investigating the requirements of other models, it was noted that a valuable addition to SURFACE would be an option for "data smoothing". Among a number of approaches, the application of a median filter (a convolution operation) during the surfacing runstream appears to be an effective and easily implemented solution.

Our investigations showed that SURFACE has applications potential for many forms of data generation in MGIS- numerical model interaction. The outputs of many numerical models, including wave refraction, current and wind forecast and/or hindcast, are structurally similar- a predicted value at a grid location. Any data structured as a set of coordinates and associated values can be processed with SURFACE.

Tide Adjustment

GIS tools can be applied to make a "global" adjustment of depths in the surf zone. Digital addition and subtraction can be operated on the baseline bathymetry to apply a very simple correction based on an externally derived value for tidal stage at a fixed time.

Over larger areas, modeling tidal effects will require a complex MGIS-model interaction in order to visualize the variation in tide levels from location to location.

Shoreline Shape and Orientation.

The LOTS planner's view of surf zone and near shore bathymetry must be complemented by detailed information about the shape and orientation of the shoreline. The importance of shoreline detail is that it provides a reference for the definition and orientation of surf zone bathymetry profiles and wave refraction bathymetry grids. Additionally, shoreline maps will typically include offshore "blocking features" the size and position of which can limit waves from reaching specific locations.

Sources of georeferenced shoreline data are numerous and GIS tools for processing shoreline data sets are well developed. From the civilian perspective, very large scale shoreline coverage is severely limited.
In MGIS, "shoreline" and "detailed" are relative. Shoreline is a more or less accurate representation of the land/water interface (hopefully compiled relative to a known tide stage). The degree of detail with which it is represented is a function of the scale at which it was mapped. Figure (2) illustrates relative differences in a representation of the same shoreline developed from two sources at scales of 1:2000000 (DMA's Digital Chart of the World) and 1:100000 (USGS DLG III). It points up the requirement for detailed coastal maps when working in the littoral zone. The global coverages of DCW, CIA WDBII are developed at so small a scale as to be unusable in the very nearshore.

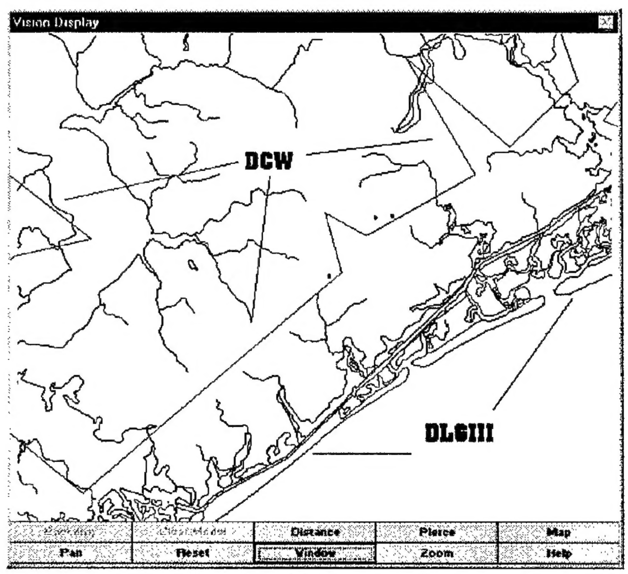


figure 2

Initially, the bathymetric map (MGIS SURFACE output) is a raster image that contains no detailed shoreline information. A vector shoreline can be laid on the bathymetry or, using specialized GIS tools, a land mask can be created to overwrite existing depth values. Figures (3) and (4) illustrate each approach.

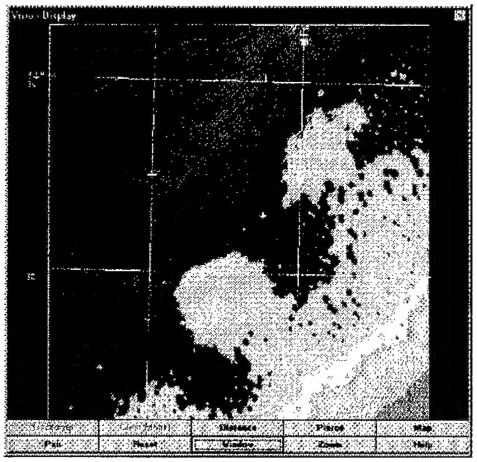


figure 3

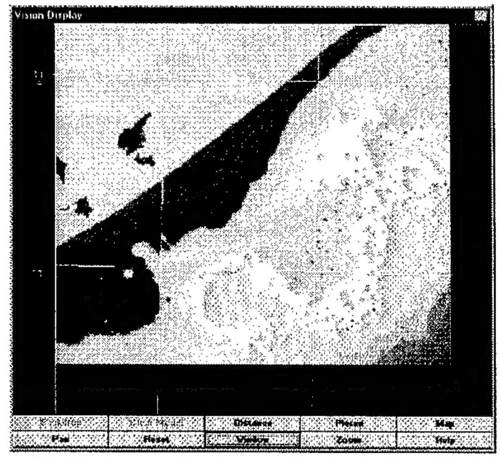


figure 4

Once bathymetry and shoreline are developed as thematic components of our conceptual MGIS, the basis for information exchange with the numerical model is established.

Meteorological and Sea State Inputs

In addition to bathymetric profiles, the SURF model requires input of (deep water) wave height, period, direction and wind speed and wind direction (preferably from local observation). This information can be developed from hindcast, forecast or near real time buoy and ship observations processed through regional wind wave models (SHALWV per RTWF document) and near shore wave refraction models (STWAVE per RTWF document and HISWA according to researchers at Woods Hole).

MGIS could rely on direct links to Naval regional and near shore wind and wave forecasts (e.g. NOGAPS, NORAPS, GOSWM, WAM area all evolving model/databases). Because model output is geographically and geometrically consistent, integration and visualization of gridded wind and wave field data is implicit in the MGIS design. A LOTS planner could interactively extract forecast wind and wave data from visualized model grids and pass these directly to wave refraction and surf models.

Feeding the SURF Model

Wind, tide and sea state inputs are requested from the LOTS planner interactively through the SURF model runstream. These are individual data elements which we assume the LOTS planner will have preprocessed and on-hand before executing SURF. Standard GIS inventory and query tools allow very rapid development of this

class of inputs from available georeferenced data or from external models (in particular, Tide level forecasting).

A key operational issue in using MGIS to feed SURF is the development of depth profile input from GIS bathymetry.

The depth profile required by SURF is a collection of depths and distances at regular intervals along a line perpendicular to the shore. Two methods of interactive SURF profile building were evaluated. Both assume that high resolution bathymetry has been (will be) developed as a thematic component of MGIS. (We note that the SURF model can be run without "real" bathymetry if an estimated bottom slope is supplied. Using actual bathymetry is preferred.)

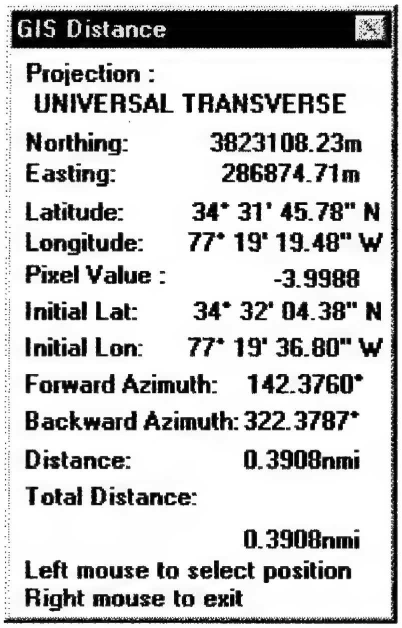
GIS Profile

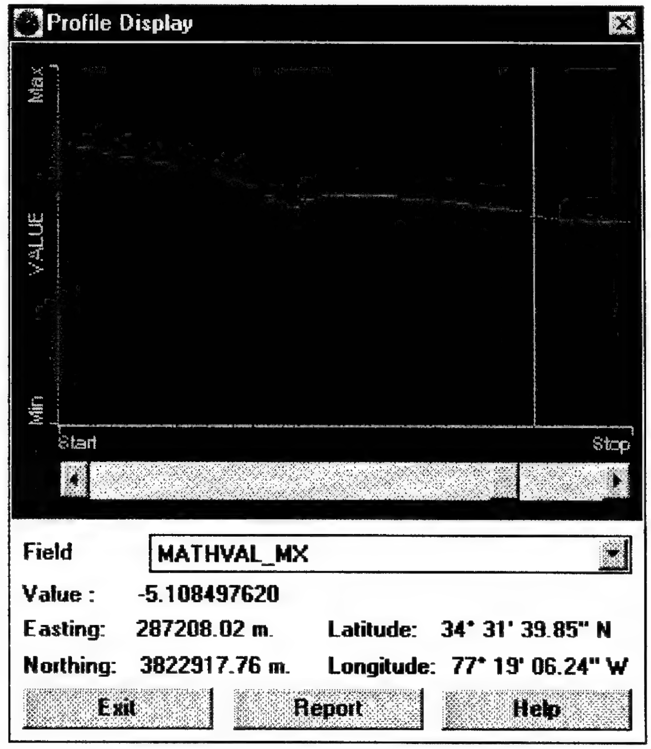
We have developed a GIS profiling tool that extracts data from a GIS theme at intervals along a user defined transect. The profile extraction can be exported as an ASCII file in the following format:

Easting	Northing	Longitude	Latitude	Depth
286295.56 m.	3824740.34 m.	77ø 19' 43.65" W	34ø 32' 38.29" N	-0.0

Positions along the transect are reported in projected and geodetic coordinates from an initial to terminal point. The point to point distances required by the current version of SURF can be easily developed from the basic profile data.

The profile is developed visually by point and click on GIS bathymetry and shoreline. A number of profiles can be generated in rapid succession. The profile interface provides the user with information on transect length and azimuth so the user has latitude in defining distances and bearings relative to a visual presentation of shoreline.



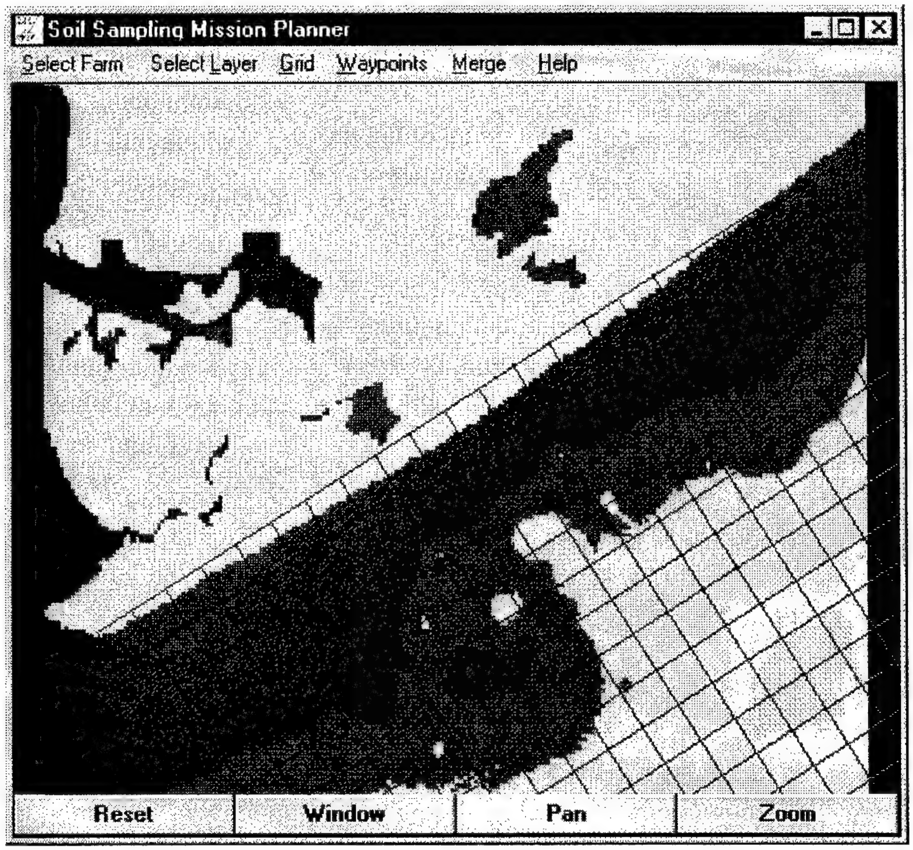


Operationally, the user has the option to build, in a more or less free form session, a variably spaced grid based on his identification of areas of interest in the surf zone. A collection of profiles can be successively processed by SURF.

<u>GIS Grid Sampling of Bathymetry</u>

It was observed that however useful interactive profiling may prove to be, a requirement exists to develop profiling by laying a rotated grid on bathymetry and extracting depths automatically at grid intersect points. We have developed a GIS tool for over the past fourteen years for customers requiring grid sampling that can be adapted to meet this requirement. Our testing was limited to a concept demonstration of grid definition and grid rotation.

The SAMPLING tool is operated on a visual display of bathymetry and shoreline. Horizontal and vertical grid spacings and grid orientation are defined interactively by the user. The grid overlay is visual and can be adjusted as necessary.



We believe that this sampling tool can be developed as the primary method of preparing bathymetry profile and bathymetry grid input to various numerical models by average users. Its principal advantage is the ease and consistency with which an "extraction grid" can be developed.

In Phase II, with variable resolution grids of wind and wave field, bathymetry and shoreline, the grid sampler should be able to extract all the local parameters required by SURF. An exception would be tide heights. These must be developed externally through a tide forecast model.

The expansion of the "extraction grid" capability would involve building a capability to extract multiple parameters (from a layering of thematic components) at each grid center or a user defined grid corner.

Visualizing SURF Model Output

The PROFILE tool was used to build four depth profiles in the surf zone. The initial ASCII output was processed into a listing of distances and depths as required by SURF. The files were transferred via e-mail to NSI offices where the SURF model was run. SURF output was returned via e-mail. We believe that this transaction was representative of a real world situation in which two LOTS operators are working

together via a digital comm-link (clearly, faster and more secure communications than e-mail would be used).

SURF output includes: the distance from shore of a modeled observation and the water depth, significant breaker height, maximum breaker height, percent breaking waves, wave length and littoral current at that distance.

Geoprocessing of SURF output first requires a conversion of distances from shore to coordinate values. In this test, the conversion was accomplished with Excel using its trig functions. X and Y are the computed UTM Zone 18N coordinates (NAD 27).

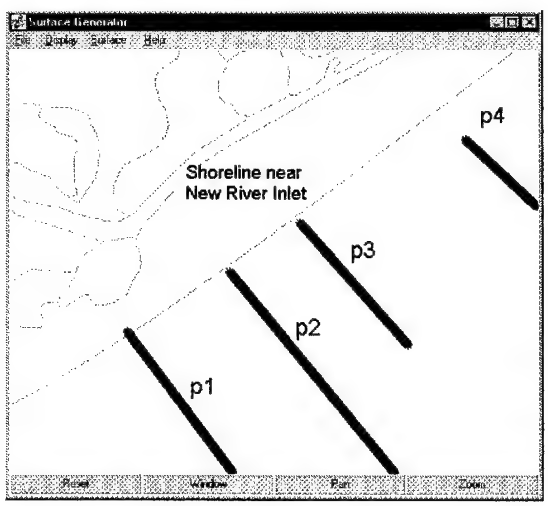
Index	Distance	Depth	B ht	Max	%B	Wave L	Current	X	Y
21	6982.3	17.2	3.1	4.8	0.1	192.2	0.08	288711.3	3822690
22	6972.3	17.2	3.1	4.8	0.1	192.2	0.08	288709.4	3822692
23	6962.3	17.2	3.1	4.8	0.1	192.2	0.09	288707.6	3822695
24	6952.3	17.2	3.1	4.8	0.1	192.2	0.09	288705.8	3822697
25	6942.3	17.2	3.1	4.8	0.1	192.2	0.09	288703.9	3822700
26	6932.3	17.2	3.1	4.8	0.1	192.2	0.09	288702.1	3822702
27	6922.3	17.2	3.1	4.8	0.1	192.2	0.09	288700.3	3822705
28	6912.3	17.2	3.1	4.8	0.1	192.2	0.09	288698.4	3822707
29	6902.3	17.2	3.1	4.8	0.1	192.2	0.09	288696.6	3822710
30	6892.3	17.2	3.1	4.8	0.1	192.2	0.09	288694.8	3822712
31	6882.3	17.2	3.1	4.8	0.1	192.2	0.09	288692.9	3822714
32	6872.3	17.2	3.1	4.7	0.1	192.2	0.09	288691.1	3822717
33	6862.3	17.2	3.1	4.7	0.1	192.2	0.09	288689.3	3822719
34	6852.3	17.2	3.1	4.7	0.1	192.2	0.09	288687.4	3822722
35	6842.3	17.1	3.1	4.7	0.1	191.6	0.09	288685.6	3822724
36	6832.3	16.9	3.1	4.7	0.1	191	0.09	288683.8	3822727
37	6822.3	16.8	3.1	4.7	0.1	190.5	0.09	288681.9	3822729
38	6812.3	16.8	3.1	4.7	0.1	190.5	0.09	288680.1	3822731
39	6802.3	16.8	3.1	4.7	0.1	190.5	0.09	288678.3	3822734

The requirement to "build in" georeferencing points to an important problem in MGIS-model interaction. Surf model output is not explicitly geographic. In the absence of a mechanism for calculating and appending geographic coordinates to each record of the surf model output, the results (in column 2) are simply point-to-point distances in an abstract, "model space". In MGIS-model interaction, "model space" and geographic space must converge before model output can be visualized in a geospatial context.

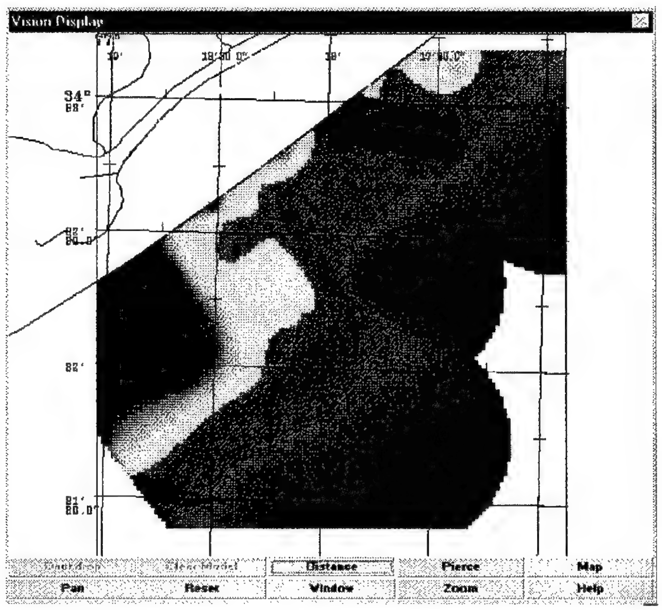
Because the profile (model bathymetry input) is extracted from a georeferenced source, we were able to recover geographic coordinate values for each surf model element based on profile start and stop locations and transect angle.

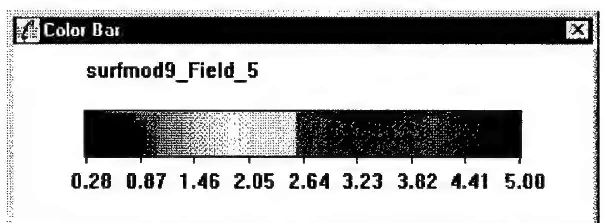
If the surf model is to be made available to MGIS operators, this convergence problem will require a transparent solution.

SURF model output in this final form (*.csv) is ready input to the SURFACE geoprocessing function. The initial plot of surf model output is illustrated below in the following figure. The "lines" are in fact points representing the individual model observations at calculated distances from shore. There were four input profiles to the model and four output sets.



Applying the SURFACE process to SURF output results in the following visualization of significant wave heights in the surf zone (scale is 1:17000) in feet:





The preceding image is important from several aspects:

1. In our view, it objectively demonstrates the feasibility of integrating geoprocessing with numerical modeling in support of LOTS. Model input bathymetry was developed inside our conceptual MGIS from a STOIC chart base. Model input was developed using an easily operated GIS tool. Model output was easily and quickly ingested and processed in a single operation (SURFACE).

The result is a georeferenced view of predicted wave activity in the surf zone near New River Inlet, NC. It functions as a highly specialized nautical chart.

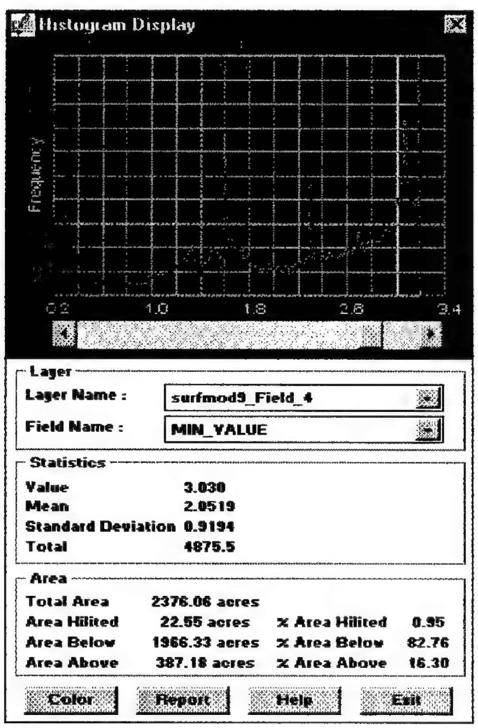
2. The image is a map- a scaled, projected representation of features in the surf zone. Using it, a LOTS planner can begin to determine what areas of the surf zone landscape are predicted to be safe for transit by specifically configured vessels.

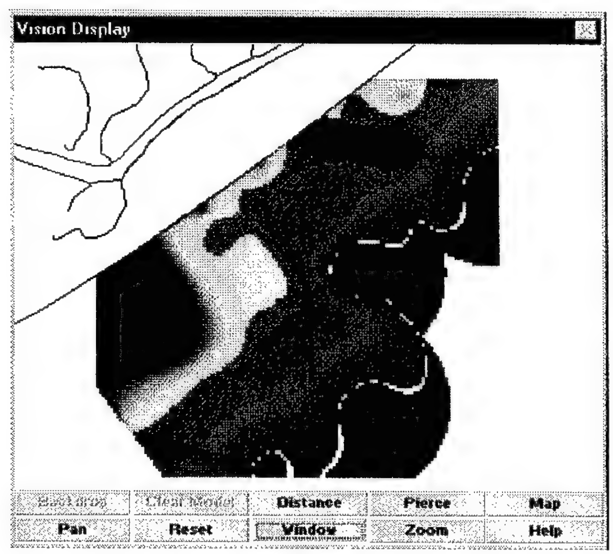
3. The image is a georeferenced, thematic component of a concept MGIS. Its spatial relationship (coincidence, proximity, adjacency) with other MGIS themes is implicit.

4. The process can be repeated through different times to develop a series of surf zone forecasts as MGIS components. The MGIS can have a temporal as well as a spatial and thematic dimension. Basic GIS theory implies an ability to build a map of composite wave activity through several forecast periods for example.

Further MGIS Analysis

The model output is a thematic component of our conceptual MGIS- the theme in this case is significant wave height. Additional analysis can be performed on the data using MGIS tools. For example, basic statistics on the frequency and spatial distribution of significant wave heights can be developed by processing the thematic map through a statistical summary and display tool. The following figure illustrates the output of this tool as it was run on the model output:





The left panel illustrates a graph of frequency distribution for various wave heights within the model viewed in the right panel. The statistics area shows the value of the current highlighted area (white contour) as 3.03 feet. The mean wave height is given as 2.06 feet and standard deviation within the model area is 0.9194. As the operator steps through the graph, the image is instantly updated to display the spatial distribution of the current step value.

MGIS operations such as this (Object Info) have value as a support to basic visualization. We anticipate an adaptation and expansion of these capabilities in Phase II.

Data Issues and Observations

General Listing of LOTS-critical parameters

We estimate that there are as many as fifty environmental parameters with significance to LOTS that must be processed in a geospatial context either as thematic maps in a forecast mode or as mixed media objects in a climate mode.

The following list outlines those identified in Phase I. Their major sources are detailed in an appendix to this report.

Climatic parameters
- Wind (speed, direction, time) and (percent occurrence for speed vs. direction, time period)
- Precipitation (type, amount, time period) and (percent occurrence)
- Severe storms (category, track, time, percent occurrence)
- Visibility (distance, time of day, percent occurrence, time period)
- Cloud cover (amount, time, probability of occurrence)
- Barometric pressure (pressure, time)
- Moonlight (phase, time, position)
- Sunlight (sunrise, sunset, twilight)
- Superstructure icing (possibility of occurrence)
- Wind chill (temperature, time)

Oceanographic parameters
- Waves (height, period, time) and (probabilities of spectrum)
- Currents (type, speed, direction, time, time period)
- Astronomic tide (type, ranges, height, time, coefficients, sample curve)
- Non-tidal fluctuations (height, time)
- Sea ice (thickness, percent cover, time, time period)
- Water temperature (percent occurrence)

Physical, geological, biological features
- Shoreline
- Bathymetry/topography
- Beach profile (depths across surf zone onto beach)
- Surface materials type (thickness, type)
- Areas of high sedimentation or erosion (area, type)

Landform/ecology/land use (type)
Vegetation (type)
Rivers, lakes
Watershed gradients

Other Physical and Cultural Features
Buildings
Roads
Piers, docks
Navigation aids, buoys
River mile points
Airstrips
Misc. man-made structures
Landmarks
Political boundaries
Place names
Vessel traffic
Obstructions

Operational parameters
Commercial shipping lanes
Navy pre-planned "Q"-routes
Landing approaches
Penetration points and lanes
Target areas, command locations
Passage height under bridges
Landing craft operational parameters
Site objectives

High Resolution Bathymetry and Shoreline

Although Work in Phase I was undertaken from a completely civilian perspective, it was supported by reasonably good data. We were able to locate accurate unclassified bathymetry (STOIC) and shoreline data in digital form. Sea state and meteorological observations were available in near real time from a number of weather and sea state observation facilities based on and off-shore (CMAN and NDBC stations).

LOTS planning operations will most likely not have immediate access to high resolution digital data, therefore, a requirement for GIS tools will be developed that focus on independent data creation by a LOTS planner.

GIS tools currently exist which are capable of supporting high resolution data development in key areas such as bathymetry and shoreline mapping. We have developed and demonstrated data generation capabilities which can be integrated in MGIS:

1. Table digitizing and heads up screen digitizing which will allow a LOTS planner to generate geoencoded soundings from digital nautical charts. (Note that creating a georeferenced digital nautical chart can be accomplished by standard scanning and geoencoding methods in a few hours. This is a mature technology.)

2. Combining remote sensing and heads up screen digitizing which allow a LOTS planner to generate high resolution shoreline maps from geoencoded satellite or airborne imagery. We believe that it is critical to recognize that geoencoded imagery is a map that can be used in MGIS as the basic visualization context for LOTS planning operations.

3. GPS-based data logging which can be used in field studies for the development of point observations of virtually any measurable event (e.g. water temperatures, clarity, salinity, bottom materials, plant and animal communities, etc.). We believe that GPS-based data logging will become a standard tool for high resolution field reconnaissance and mapping.

Regional and Global Data

LOTS planners will often rely on medium and low resolution data for generalized mapping and interpretation support.

In our Phase I investigations of regional and global data, we surveyed the developing information systems at Fleet Numerical and Navoceano (e.g. Navoceano's IDBMS). The data holdings and basic data characteristics are well documented in literature distributed by COMNAVMETOCCOM.

Phase I has demonstrated the general ability to process and to visualize geoencoded data. Most of the data referenced in the Meteorological and Oceanographic Data for Modeling and Simulation publication is either geoencoded point or gridded data. If we can extract data subsets, we can process them into a geographic visualizations (maps) and integrate them as thematic components of a MGIS project. Indications from system descriptions of Navoceano IDBMS, NMDC' GLIS and NOAA's NODDS are that data subsets can be extracted. The same geoprocessing tools that were applied to high resolution data can be used with data developed from regional and global data. From the standpoint of projected MGIS capabilities, the only operational difference between the geoencoded STOIC soundings and data from DBDB-1, DBDB-2, DBDB-5 or ETOPO is scale.

SQL-based mechanisms for data set extraction are being developed within Navoceano's IDBMS. At this point, we believe that an efficient course for Phase II work would be to use IDBMS as a gateway for regional and global data retrieval in the development of MGIS projects.

Special Issue: The Presentation of Tabular and Unmapped Imagery

Not all LOTS operators will be directly concerned with mapping and numerical model interaction. There is a class of operators who are concerned with rapidly developing basic site descriptions in tabular and graph form.

Geoprocessing technology has advanced to a point at which geoencoded objects can be attributed with external objects or applications. It is currently possible to link an object or location in a map with a document, spreadsheet, static image or mpeg.

The possibilities for extending MGIS to operation in a historic or "climate mode" are very interesting. We believe that a basic map interface can be developed as a set of visual access keys to tabular and non-georeferenced imagery. A user can click on a feature in a map and immediately access an mpeg player to run video of an aerial overflight or to view a graph of historic wave activity or climate data.

The conceptual MGIS demonstrated this operating concept by accessing an external tide prediction tool within the general MGIS application when the user clicked anywhere in the offshore area of one of the thematic components.

Without trivializing the data development and data management challenges, we note that "mixed-media" capabilities are available in current GIS design. We believe that they can perform valuable functions within MGIS.

Summary and Conclusions

1. Geoprocessing (GIS) is a mature technology that can effectively support LOTS. This Phase I effort has effectively demonstrated the capability of PC-based geoprocessing to integrate environmental data, including the output of a numerical surf forecast model, in a visual, georeferenced information system. The general feasibility of MGIS was established in Phase I.

2. A critical question was the feasibility and degree of difficulty involved in developing an interaction between numerical models and GIS. To the extent that we succeeded in designing a basic interaction between the Navy surf model and a conceptual MGIS, general feasibility was addressed.

We believe that the MGIS-surf model interaction demonstrated a basic transaction structure that will be repeated in interactions with other wave and surf forecast models, notably the current and future generations of STWAVE and HISWA. We expect to offer LOTS planners a range of model interaction options based on their level of comfort with a given model.

We are convinced that the "user intensity" of MGIS/numerical model interactions can be managed through the development of application specific software in a Phase II effort.

3. Phase I also demonstrated the facility with which critical high resolution bathymetry can be developed using standard geoprocessing tools. Several methods for developing high resolution bathymetric and shoreline maps were identified. We note that our experience with these methods is significant and predates this Phase I work.

4. The mechanics of populating a MGIS project with geospatial data are well established in current GIS technology. Questions concerning actual data availability, quality and utility in LOTS planning remain. We see major issues relating to the resolution of regional and global data sets and their ultimate utility to LOTS planning in the littoral zone.

Some 50 LOTS-critical data requirements were identified and sources of these data were surveyed.

The majority of these data exist as geoencoded grids or point observations. As such, they are available to GIS integration. The general operating theory of information systems such as NOAA NODDS and NAVOCEANO IDBMS indicates that global and regional data location and retrieval are feasible.

Because much of the data is distributed in ASCII format, data ingest issues will be manageable. Data in this form can be processed using currently designed geoprocessing tools. The SURFACE application demonstrated a well developed capability for ingest and processing of this significant class of geospatial data.

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Navigation Information Network (NAVINFONET) ARC Digital Raster Imagery (ADRI)
ARC Digitized Raster Graphics (ADRG) World Vector Shoreline (WVS)
Digital Nautical Chart (DNC)
Multispectral Imagery (MSI) Digital Sailing directions (DSD) Vector Smart Map Urban (VSMU)

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List of Relevant Data Bases for Marine GIS

Name	Acronym	Source	Parameters	Description	Status
	ATLAST	JPL	Pot.Temp. , Pressure, O2, S, Density, Phosphate, Nitrate, Si	Global areal coverage.	
Advanced Very High Resolution Radiometer (1)	AVHRR (1)	NRL	SST	Global, weekly coverage from 1982 to 1990. Spatial resolution is 18 km.	
Dynamic GDEM	DGDEM	NAVOCEANO	T, S, SS	Developed for specific small regions.	
Generalized Digital Environmental Model Data Base	GDEM	COMNAVMETOCCOM	T, S, SS	U.S. Navy standard oceanographic climatology from 1902 to present with 1/2-degree horizontal resolution, 36 vertical levels and four seasons. Coverage is regional (N.Atl., N.Pac., Med., Indian), and is limited to areas 400 m or greater in depth.	
Under Ice Roughness and Ridge Frequency Data Base	ICECAP	COMNAVMETOCCOM	Ice Thickness, Ice Keel	Digital ice profile statistics from several submarine cruises forecast or updated every 3 years. Spatial coverage includes from 60° to 90°N with spatial resolution of 1° lat. by 2.5° long. from 1977-1991.	
Levitus		NOAA	T, S, O2, DO, Potential Temp, BV freq., Potential Density	Global coverage for four seasons. Spatial resolution is 1° (horiz.), with 33 vertical levels.	
ONR Shallow Water Data Base	ONRSWDB	ONR	T, S	Regional coverage for four seasons. Spatial coverage is northern hemisphere, non-U.S. coastal areas with spatial resolution of 5 min. in horizontal.	
Shea-Trenberth-Reynolds SST	STR SST	NCAR	SST	Global coverage with spatial resolution of 2° x 2° and monthly temporal resolution.	
Wave Data	WISWAVE	CERC	Significant Wave Height, Peak Wave Period, Peak Wave Direction	Hindcast modeled data for each 3 -hours for period 1956-1975. One quarter degree intervals in 10 m water depth along coastline.	
Wave Data	WISWAVE	CERC	Directional Wave Energy Spectrum (horiz. position, freq, dir, time)	Hindcast modeled data for each 3-hours for 1956-1975. Twenty spectral bands, 16 direction bands. Spatial coverage is Atlantic, Great Lakes, and southern California.	
Advanced Very High Resolution Radiometer (2)	AVHRR (2)	NRL	SST	Regional scenes from 1993 to the present. Spatial coverage is Gulf of Mexico and Arabian Sea with scenes of 1 km.	
Advanced Very High Resolution Radiometer (3)	AVHRR (3)	NRL	Turbidity (c(660))	Coastal Gulf of Mexico coverage from April 1994 to present, with spatial resolution of 1 km.	
Bathythermograph Soundings	BATHY	FLENUMMETOCCEN	Conductivity, Salinity, T, Water Depth	Global point data taken from XBT's and CTD's for 1901 to present.	
Antarctic Icebergs	BERG	NAVICECEN		Information on tabular icebergs in the southern hemisphere, south of 45° lat. from 1979 to present. Spatial resolution is 10 km.	

Oceanographic Drifting Buoy Data	BUOY	FLENUMMETOCCEN	Drift and Wind Speed and Direction, Air Temp., Dew Point, Humidity, P, Sea-level Press., Pressure Tendency, S, T, Wave Period, Wave Height, Water Depth	Global data bank of data reported from oceanographic drifting buoys for 1901 to present.	
Coastal Engineering Data Retrieval System	CEDRS	CERC	Wave Height/Period/Direction; Wind Speed/Direction	Hindcast and measured data from 1956 to present. Hindcast data are from Wave Information Studies (WIS) which are time series produced from a computer hindcast model. Coverage is the Atl. and Gulf of Mexico, with future coverage the Pac. and Great Lakes.	
Front and Eddy Composite v1.0	COMPOSITE v1.0	NAVOCEANO	T	Both observed and extrapolated limits combined to display the complete front position and boundaries of water masses from 1988 to present. Spatial coverage is N.Atl., N. Pac., W. Indian, Med. Sea,and GIUK with spatial resolution of 1.1 km.	
Front and Eddy Analysis	DAILIES	NAVOCEANO	T, Surface Frontal Positions of Currents and Eddies	Surface position of ocean features derived from AVHRR / IR satellite imagery for 1988 to present. Spatial coverage is N.Atl., N. Pac., W. Indian, Med. Sea,and GIUK with spatial resolution of 1.1 km.	
Geostationary Operational Environmental Satellite Imagery	GOES	NRL-MRY	SST	Regional imagery available every 30 minutes for both visible (1 km) and IR (4 km).	
Sea Ice Climatology	ICECLIMO	COMNAVMETOCCOM	Maximum, Mean, and Minimum Ice edges and extent of 5/10ths or more ice	Ice climatology derived from 23 years of ice analyses in SIGRID database. Provides global coverage north and south of 45° lat. from 1972 to present with spatial resolution of 15 nmi.	
Multi-Channel Sea Surface Temperature	MCSST	NAVOCEANO	SST	From Advanced Very High Resolution Radiometer (AVHRR) on board NOAA polar-orbiting satellites. Global coverage with 8 km spatial resolution.	
Master Oceanographic Observation Data Set	MOODS	NAVOCEANO	D, S, P, SSP	Global coverage of observed data and vertical profiles of D/T point data from 1901 to present. Includes much of NODC historical profiles.	
NODC Historical Temp. & Salinity Profiles		NOAA/NODC	T, S	Global historical data at varying spatial resolutions.	
Salinity Geophysics Bathymetry Temperature	SAGEBATE	NAVOCEANO	Bathymetry, SST, Magnetics, 6 Seismic Horizons	Global coverage with spatial resolution of 0.0001° lat. & long. from 1967 to present.	
Enhanced Satellite Imagery	SATMSG	NAVOCEANO	SST	High-resolution IR satellite imagery from the AVHRR sensor aboard polar orbiting satellites. Spatial coverage is N.Atl., N. Pac., W. Indian, Med. Sea,and GIUK with spatial resolution of 1.1 km.	
Surface Currents Data Base	SCDB	NAVOCEANO	SS, V, T	Multinational observations of surface current derived from ship set and drift. Spatial coverage is global point data mostly along shipping lanes.	

Surface Ship Observations	SHIP SYNOPTIC	FLENUMMETOCCEN	Wind Speed and Direction, Humidity, Sea-Level Pressure, T, Precipitation, Cloud Height, Sea Height, Swell	Surface weather point data taken from ship stations retained up to 30 days.	
Sea Ice Gridded Data	SIGRID	WDC-A / NSIDC	Satellite Imagery, Drifting Buoys, Aerial Reconnaissance	Derived from weekly Arctic and Antarctic ice analyses, and reside in compacted raster format known as SIGRID. Spatial coverage is north of 45°N and south of 45°S with spatial resolution of 15 nmi from 1972 to present.	
Standard Navy Altimetry Record	SNAR	NAVOCEANO	SSH, WS/WD, WH, Ice edges	Global data bank with a satellite dependent spatial resolution with ground track spacing plus 7 km along track. Updated every 1 to 10 hours. Data not retained.	
Subsurface Currents Data Base	SSCDB	NAVOCEANO	Velocity, T, Water Depth	Global data base primarily of coastal areas containing point data from 1960 to present.	
Wave Data		NOAA	Significant Wave Height, Mean Wave Period, Dominant Wave Period, Wave Spectrum	Measured by NOAA wave buoys.	
Wave Data		CERC	Wave Spectrum	Measured by CERC buoys, pressure gauges, etc.	
Bathymetry					
3-DIMENSIONAL THERMAL FIELDS	3-D TDS	NAVOCEANO	Thermal Field	Gridded fields from optimal interpolations for selected regions. Data from MCSST's, BT's, drifting buoys, etc. are assimilated into climatological start-up fields.	
Advanced Circulation	ADCIRC	CERC	Sea-surface Elevation, Depth-averaged Tidal Currents	Finite element regional oceanographic model with very high resolution on the continental shelf and slope waters. Spatial resolution is 100 m to 10 km.	
Data Assimilation Reserach Transmission	DART (Gulf Stream)	FLENUMMETOCCEN	Dynamic Height	Forecasts up to 7 and 14 days for the Gulf Stream region with spatial resolution of 1/8°. Updated 3 times per week.	
Expanded Ocean Thermal Structure	EOTS	FLENUMMETOCCEN	Thermal Fields	Regional ocean thermal nowcast model using variational technique called Fields-by-Information-Blending (FIB).	
Global Spectral Ocean Wave Model	GSOWM	FLENUMMETOCCEN	Direction Wave Energy Spectra	Global forecasts of directional wave energy spectra from which significant wave height, primary wave period, and primary wave direction are derived. Uses forcing provided by NOGAPS.	
Modular Ocean Data Assimilation System	MODAS	NAVOCEANO	Temperature, Salinity, Sound Speed	High resolution 3-D gridded fields from optimum interpolation. Restricted to deep water applications.	

Optimum Thermal Interplation System	OTIS	FLENUMMETOCCEN	Dynamic Height, Salinity, Temperature, Temperature Anomalies, Temp. Errors	Global (SST only) and regional (Gulf Stream, Kuroshio, Greenland, Iceland, Norwegian Sea (GINS)) 3-D nowcast fields. Spatial resolutions are 1° (global) and 0.2° (regional) and updates occur on 12-hour (global) and 24-hour (regional) cycles.	
Polar Ice Prediction System	PIPS	FLENUMMETOCCEN	Arctic Ice Drift, Thickness, Concentration, Divergence/Convergence, Ice Growth, Strength	Gridded forecasts (up to 120 hours) of the Arctic Basin, Barents Sea, and Greenland Sea updated on 1-week cycles. Spatial resolutions are 127-km grid cells (Arctic Basin) and 20- to 30-km grid cells (regional).	
Princeton Model	POM	Princeton	Circulation	Multi-level primitive equation ocean circulation model. Includes atmospheric and tidal forcing and is designed specifically for high resolution shallow water applications. Model is run for Persian Gulf and Red Sea. Atl., Pac., Indian for future.	
Shallow Water Analysis and Nowcast System	SWANS	NAVOCEANO	Temperature, Salinity, Sound Speed, Mixed Layer Depth	Optimum interpolation real-time data assimilator coupled with the Princeton Model. Implemented in semi-enclosed seas dominated by shallow water.	
Spectral Wave Prediction System	SWAPS	NAVOCEANO	Spectral Surface Gravity Waves	Spectral surface gravity wave prediction system, consisting of a two-dimensional spectral wave model (WAM), tailored to those semi-enclosed seas for which NAVOCEANO has twice daily forecast responsibility. Coverage is Med. Sea.	
Thermodynamics Ocean Prediction System 4.0	TOPS 4.0	FLENUMMETOCCEN	Upper Ocean Temperature, Thermal Fields, Derived Surface Currents	Global and regional (Gulf Stream, Kuroshio) forecasts to 36-hours minimum, 72-hours maximum. Spatial resolutions are 1° (global) and 0.2° (regional). Updated daily.	
Wave Model	WAM	FLENUMMETOCCEN	Directiona Wave Energy Spectra, Derived Significant Wave Height, Mean Period, Peak Direction, Sea and Swell Heigh, Period, Direction	Global forecast to 72 hours and regional forecasts of Indian Ocean, Med. Sea, and Korean region to 48 hours. Spatial resolutions are 1° (global) and 0.2° to 25° (regional).	
Wave Model	WAM	NAVOCEANO	Wave height, Period, Direction, Directional Energy Spectra	Gridded analysis and forecast of the previous parameters and has a spatial coverage of selected regions (dependent on requirements) that is forecast every 48 hours and updated 2 times per year.	
DATA SET METADATA DATABASE		Marine Corps M&S Management Office		Incorporated into the AAAV Sources Relational Database.	
DATA ELEMENT METADATA DATABASE		Marine Corps M&S Management Office		Incorporated into the AAAV Sources Relational Database.	
MODEL/SIMULATION METADATA DATABASE		Marine Corps M&S Management Office		Incorporated into the AAAV Sources Relational Database.	

Digital Bathymetric Data Base - 1	DBDB-1	DMA	Water Depth	Depths for every oceanic geographic position evenly divisible by 1 minute of latitude and longitude in selected areas. Present (1995) coverage is Med. Sea and southern California.	
Digital Bathymetric Data Base - 2	DBDB-2	DMA	Water Depth	Depths for every oceanic geographic position evenly divisible by 2 minutes of latitude and longitude in selected areas. Present (1995) coverage is the Med. Sea, Red Sea, Persian Gulf, and northern Gulf of Oman.	
Digital Bathymetric Data Base - 5	DBDB-5	DMA	Water Depth	Depths for every oceanic geographic position evenly divisible by 5 minutes of latitude and longitude in selected areas. Present (1995) coverage is all ocean areas north of 78°S.	
Digital Bathymetric Data Base - C	DBDB-C	DMA	Water Depth	Depths provided for every oceanic geographic position evenly divisible by 5 minutes of latitude and longitude in selected areas. Spatial coverage is all ocean areas north of 78°S. (CONFIDENTIAL)	
15" Bathymetry	TOPO15	NOAA/NOS	Bathymetry	15" soundings sporadic throughout coastal waters of CONUS.	
5' Topography	ETOPO5	NOAA/NGDC	Depth, Elevation	Global coverage with spatial resolutions of 5 min. (horiz.) and 1 m (vertical).	
TerrainBase		NOAA/NGDC	Depth, Elevation	Updated ETOPO5 which provides global coverage at higher resolutions.	
30" Topography	TOPO30	USGS/NOAA	Bathymetry, Hypsography	30" postings of entire CONUS which can be intersected with ETOPO5 at a 30" sampling to form higher resolution TOPO data set.	
World Vector Shoreline	WVS	DMA	Shoreline Position	High-resolution, vectorized global coverage.	
World Vector Shoreline Plus	WVS Plus	DMA	Shoreline Position	High-resolution, polygonized global coverage.	
Arc Digitized Raster Graphics	ADRG	DMA	Underwater Obstructions, Water Depth, Tidal Currents, Vegetation, Bottom Materials Type, Shoreline Position, Population Centers, Waterways, Railroads, Physiographic Features	Digital raster representations of hardcopy charts, such as Navigation Charts, City Maps, Pilotage Charts, Combat Charts, and Nautical Charts. Available for most CONUS areas.	
Bathythermograph Soundings	BATHY	FLENUMMETOCCEN	Conductivity, Salinity, T, Water Depth	Observations of subsurface temperatures taken from expendable bathythermographs for 1901 to present.	
Digital Chart of the World	DCW	DMA	Coastlines, Populated Places, Road and Rail Networks	Global coverage at map scale of 1:1,000,000.	
Digital Feature Analysis Data	DFAD	DMA	Lines of Communication, Waterways/Rivers, Urban Areas, Surface Material, Vegetation, Roads/Railroads	Global coverage in grid sizes of 1°x 1°, 2 x 2 nmi, and 10 x 10 nmi.	

Digital Nautical Chart	DNC	DMA	Surface Material, Waterways/Rivers, Obstructions, High-water Line	Plans to provide global coverage, but presently provides specific local coverage. The spatial coverage includes Hampton Roads and Virginia Capes test areas, as well as New York Harbor.	
Digital Terrain Elevation Data	DTED	DMA	Terrain Elevation, Slope, Surface Roughness	Global coverage in grid sizes of 1° x 1°.	
Coastal Shoreline		NRL	Coastal Shoreline Position	Global coastal shoreline positions with spatial resolutions of 0.2 km.	
Interim Terrain Data	ITD	DMA	Surface Material, Slope, Vegetation, Transportation, Obstacles	Limited regional coverage. Present (1995) coverage is parts of the Middle East, Central Europe, and Korea. Central America, SE Asia, and the U.S. are planned for future.	
NOS 80K Shoreline	NOS80	NOAA/NOS	Shoreline Position	Spatial coverage is entire east coast, Gulf of Mexico, and Great Lakes. New CONUS sub-sets being developed.	
Special Sensor Microwave Imager	SSMI	FLENUMMETOCCEN	Land Surface Type and Temp., Snow Extent, Snow Depth, Soil Moisture, Ocean Surface Wind Speed, Ice Concentration, Ice Age, Water Vapor, Rain Rate	Global data bank of parameters derived from multifrequency microwave SSMI. Data retained up to 30 days.	
SYNBAPS Bathymetric	SYNBAPS	NRL	Water Depth	Global coverage with spatial resolution of 10 km.	
Historical Temporal Shipping	HITS	COMNAVMETOCCOM	Surface Shipping Density, Type	Covers ocean areas between 60°S and 80°N with a spatial resoltuion of 1° arc of lat. by 1° arc of long. from 1978 to 1990. Updated every 2 years.	
Bottom Backscatter	BBS	NAVOCEANO	Sound-Source Type (SUS, CW, etc.), Weight or Pulse, Water Depth, Receiver Depth, Frequency, Beam Angle, Grazing Angle, and Scattering Levels	Point data from the N. Atl., and Med. Sea updated every 6 months. Temporal coverage is from 1967 to present.	
High-Frequency Bottom Loss	HFBL	COMNAVMETOCCOM	Geoacoustic Provinces, Sediment Thickness, Bottom Loss, Grazing Angle	Reflective and refractive characteristics of ocean bottoms for frequencies 1.5 kHz to 4.0 kHz. Spatial coverage is selected areas of the Atl., Pac., Indian, Arctic, and Med. Sea from 1985 to present with spatial resolution of 5 min. lat. & long.	
Low-Frequency Bottom Loss	LFBL	COMNAVMETOCCOM	Sediment Thickness, Bottom Loss, Grazing Angle	Reflective and refractive characteristics of the ocean bottom. Spatial coverage is selected areas of the Atl., Pac., Indian, Arctic, and Med. Sea from 1985 to present with spatial resolution of 5 min. lat. & long.	
Master Oceanographic Observation Data Set	MOODS	NAVOCEANO	D, S, P, SSP	Global coverage of observed data and vertical profiles of point data from 1901 to present.	
Shipping Noise - Directional Ambient Noise	SN - DIAN	COMNAVMETOCCOM	Shipping Noise	Estimated horizontal directional shipping noise in N. Atl. and N. Pac. from 1985 to present. Limited to water depth greater than 1200 ft. Spatial resolution is 1° lat. & long. with 1.5° for Med Sea.	

Shipping Noise - Historical Ice-Edge	SN - HIE	COMNAVMETOCCOM	Shipping Noise	Monthly mean ice edge and the surrounding Marginal Ice Zone (MIZ) of parts of the western Pacific and Arctic. Spatial resolution is 5 min. lat. & long. with coverage from 1986 to present.	
Shipping Noise - Low Resolution Shipping Noise	SN - LRSN	COMNAVMETOCCOM	Shipping Noise	Estimated omnidirectional and horizontally directional shipping noise and spectra for selected areas of the N. Atl., N. Pac., Indian, and Norwegian Sea, from 1985 to present.	
Volume Scattering Strength	VSS	COMNAVMETOCCOM	Column Scattering Strength	Integrated scattering strength data by season on 5° square grid cells. Spatial coverage is 80°S to 90°N from 1979 to 1994. Updated every 6 months.	
Coastal Zone Color Scanner (1)	CZCS (1)	NRL	Chlorophyll, k(490)	Global, monthly coverage from 1978-1986 with swath width of 18 km.	
Coastal Zone Color Scanner (2)	CZCS (2)	NRL	Chlorophyll, k (490), 4 Spectral Radiance Aerosols (670 nm)	Regional imagery from 1978 to 1986. Spatial coverage is Arabian Sea, Sea of Japan, and Gulf of Mexico with a spatial resolution of 1 km.	
Solar Irradiance		NRL	Solar Irradiance at Sea Surface	Regional, monthly coverage from 1979 to 1982. Spatial coverage is the North Atlantic, Arabian Sea, and Pacific with a spatial resolution of 18 km.	
3-Dimensional Nephanalysis	3DNEPH	USAETAC	Percent Cloud Coverage,Cloud Type(low,middle,high),Min.Cloud Base,Total Coverage,Cloud Base,Cloud Top,Weather Report	Worldwide coverage of the Northern Hemisphere from 1/73 to 12/83, and Southern Hemisphere from 1/77 to 12/83. Resolution 513x513 polar stereograph, 26 nm at 60°, 15 layers (6 layers: surface-3,500 ft; 9 layers: surface-40,000 ft).	
3-Dimensional Nephanalysis Low,Middle,High Type/Amount	3DNEPH-LMHT/A	USAETAC	Cloud Type and Amount (low,middle,high),Total Cloud Coverage	Worldwide coverage of the Northern Hemisphere from 1/73 to 12/83, and Southern Hemisphere from 1/77 to 12/83. Resolution 512x512 polar stereograph, 26 nm at 60°.	
AGROMET	AGROMET	USAETAC	Temperature, Moisture, Radiation, etc.	Geographic coverage is all land areas.	
Cloud Cover		NRL	Cloud Cover	Regional, monthly images from 1978 to 1986. Spatial coverage is the Pacific Ocean and Arabian Sea, with a spatial resolution of 18 km and temporal resolution of 3 hours.	
Coarse Mesh Upper-Air		USAFETAC	Wind Component(u,v), D-Value, Sea Level Pressure,Temperature,Dew Point Temperature,U-V Cross Product,Density	Worldwide coverage from 1/77-12/84. Resolution 65x65 polar stereograph, 206 nm at 60°; tropical strip 73x19 mercador. Mandatory pressure levels (surface, 1000,850,700,500,400,300,250,200,150,100,70,50, 30, 20, and 10 MB).	
Historical Wind Speed	HWS	COMNAVMETOCCOM	Surface Wind Speed Statistics	Monthly global ocean surface wind statistics from 1946 to 1986, with a spatial resolution of 1° latitude and longitude.	

Liquid Water Content		USAFETAC	Cloud Type(low,middle,high), Total Cloud Amount, Weather, Cloud Base, Cloud Top, Temperature, Density, Ice Content(Cloud&Rain), Liquid Content(Cloud&Rain)	Coverage of Northern Hemisphere from 1/77 to 12/80. Resolution 15 layers (6 layers: surface-3,500 ft; 9 layers: surface-40,000 ft).	
Ozone		NRL	Ozone Concentration	Global coverage from 1978 to 1986 with a spatial resolution of 50 km.	
Ozone Data		USAFETAC	Total Amount of Ozone, Ozone Partial Pressure, Air Temperature, Wind Direction, Wind Speed	Coverage from 1/57 to 12/80.	
Summarized Coarse Mesh Analysis (UAPIP)		USAFETAC	Wind Component (u,v), D-Value, Sea Level Pressure, Temperature, Dew Point Depression, U-V Cross Product, Density, Summation	Worldwide coverage from 1/77 to 12/83. Spatial resolution 65x65 polar stereograph, 206nm at 60°. Mandatory pressure levels (surface, 1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, and 10mb).	
Surface Wind		NMC/FNMOC	Wind Direction/Speed	Computed from pressure fields at WISWAVE grid points. Average wind at 10 m elevation.	
TDF-13 (Foreign Synoptic)		USAFETAC	Wind Dir/Speed, Barometric Pressures, Pressure Tendency and Change, Temperature(dry bulb, dew point), Visibility, Total Sky Cover, Cloud Layer Data, Present Weather	Worldwide (not U.S.) coverage from 1901-1971 for 6.000 foreign stations.	
TDF-14 (Airways/METAR)		USAFETAC	Wind Dir/Speed, Barometric Pressures, Pressure Tendency and Change, Temperature(dry bulb, dew point), Visibility, Ceiling, Cloud Layer Groups, Present Weather	Worldwide coverage from 1929-1970 for 2,566 stations.	
TDF-34 (Summary of the Day)		USAFETAC	Temperature(mean,min,max), Peak Wind, Precipitation, Snowfall, Snow Depth, Days with thunderstorms, sleet, hail, dust, smoke, snow, blowing snow, rain, fog	Worldwide coverage from 1890-1992 for 1,795 stations.	
TDF-35 (West German Summary)		USAFETAC	Temperature (mean,min,max), Total Precipitation, Sunshine Hours, Snow Cover,	West Germany coverage from 1953-1980 for 116 West German stations.	
TDF-52 (Foreign PIBAL)		USAFETAC	Wind Speed, Wind Direction	Worldwide (not U.S.) coverage from 1922-1970 for 1,217 foreign stations.	
TDF-53 (Worldwide Winds Aloft)		USAFETAC	Wind Speed, Wind Direction	Worldwide coverage from 1919-1965 for 1,660 stations with varying levels.	
TDF-54 (Worldwide Radiosonde)		USAFETAC	Height, Temperature, Pressure, Relative Humidity, Wind Direction, Wind Speed	Worldwide coverage from 1930-1970 for 1,170 stations with varying levels.	

TDF-56 (Worldwide Rawinsonde)		USAFETAC	Height, Temperature, Pressure, Relative Humidity, Wind Direction, Wind Speed	Worldwide coverage from 1946-1970 for 699 stations. Mandatory pressure levels (surface, 1000,850,700,	
TDF-57 (Worldwide RECCO, Dropsonde, Flight Weather)		USAFETAC	Height, Wind Direction, Wind Speed, Temperature, Cloud Data, Pressure	Worldwide coverage from 1947 to 1958.	
Wind and Residual Noise	WRN	COMNAVMETOCCOM	Spectra for Wind-Generated Noise, Presence of Transient and/or Residual Noise Sources	Spatial coverage of the N.Atl., Norwegian Sea, Indian Ocean, and Med. Sea from 1985 to 1989 and is updated twice a year.	
World WeatherDisc		WeatherDisc Associates, Inc. Seattle, WA	Air Temp., RH, Dew Pt., Precip., Winds, Storms, SST, Daily Weather Obs., Sunshine Data, etc.	Six global and 11 U.S. data sets of varying spatial and temporal resolutions.	
Aircraft Reports	AIREPS	FLENUMMETOCCEN	Upper Level Winds, Temp.	Global point data reported from aircraft of opportunity and retained up to 30 days.	
Surface Aviation Observations	AIRWAYS	FLENUMMETOCCEN	Air Temperature, Dew Point, Winds, Pressure, Altimeter, Clouds	Surface weather reports from CONUS airport locations, as well as Alaska, Canada, Hawaii, and Mexico. Observations retained for 30 days, and updated hourly.	
Aircraft Meteorology Data Relay	AMDAR	FLENUMMETOCCEN	Flight level, Location, Pressure, Air Temperature, Dew Point, Humidity, Wind Speed and Direction, Turbulence, Vertical Gusts	Automated meteorological observations from aircraft of opportunity. Global coverage of point data retained up to 30 days.	
Boundary Layer Windows		USAETAC	Wind Component(u,v,w), Temperature, D-Value,Height Above Mean Sea Level, Humidity (specific,relative),Specific Moisture,Fractional Wind Field(u,v).	Coverage of U.S.,Europe from 1/77-present; Asia from 1/77-12/77 and 4/81-present. Resolution 29x27 U.S. or 29x35, 103 nm at 60°, eight levels (surface,50,150,300,600,900,1200, and 1600 meters).	
Arctic Drifting Buoys	BUOYS	WDC-A / NSIDC	Positions, Barometric Pressure, Air Temp.	Spatial resolution of 300 m from 1979 to present with northern hemisphere polar region coverage.	
	DATSAV2	USAFETAC	Wind Dir/Speed, Pressure, Temp/Dew Point Temp, Total Sky Cover, Visibility, Past & Present Weather, Cloud Layer Data, Ceiling, Precip, Runway Data, Ship Data	Global surface point data for 13,000 stations.	
	DATSAV Airfcraft	USAFETAC	Wind Dir/Speed, Temp, Dew Point Depression, Turbulence, Icing Data, Cloud and Contrail Data, Weather, Flight Visibility, Radar Data, D-Value, Altitude of Mandatory Pressure Level	Worldwide coverage from 10/75 to present. Greatest concentration resolution over U.S. and along major air routes.	

	DATSAV Rocketsonde	USAETAC	Height, Temperature, Pressure, Wind Direction, Wind Speed, Density	Worldwide coverage from 10/75 to present. Resolution is altitude of 20 km to 60 km.	
	DATSAV Satellite	USAETAC	Height, Temperature, Wind Direction, Wind Speed	Worldwide coverage from 10/75 to present. Resolution from surface to 10 mb.	
	DATASAV UPPER AIR	USAFETAC	Pressure, Height, Temp., Dew Pint Depression, Wind Dir/Speed, Cloud Data, SSI, SWEAT Index, Thickness, Precipitable Water, Saturation Moisture Ratio, Turbulence	Global upper air point data from the surface to 10 mb.	
Eighth Mesh Surface Temperature		USAFETAC	Surface Temperature	Worldwide coverage from 4/79 to present. Resolution 512x512 polar stereograph, 26 nm at 60°, each synoptic hour.	
Global Tropical Cyclone Tracks Data Base	GTCT	FLENUMMETOC DET Asheville	Time, Position, Mode of Movement, Maximum Wind Speed, Sea-Level Pressure, Dvorak T-Number, Dvorak CI-Number, Intensity Stage	Consolidation of historical data sources for global tropical cyclones from 1842 to 1992, updated annually. Spatial coverage is parts of the Atlantic, Pacific, and Indian Ocean with 0.1° spatial resolution.	
Hellermean-Rosenstein Wind Stress			Wind Stress		
High Resolution Analysis System	HRAS	USAFETAC	Sea-level Pressure, Wind Component (u,v), D-Value, Temperature, Dew Point Depression, Specific Humidity, Tropopause Pressure,Height, Temperature, Vertical Velocity	Worldwide coverage from 1/85 to present. Resolution 2.5x2.5° grid. Mandatory pressure levels (surface, 1000, 850,700,500,400,300,250,200,150,100,70,50, 30,20 and 10 mb).	
Surface Land Observations	LAND SYNOPIC	FLENUMMETOCCEN	Wind Speed and Direction, Humidity, Sea-Level Pressure, T, Precipitation, Cloud-Base Height	Global point data of land-station surface weather observations taken at synoptic reporting times.	
	NEXRAD	WSI	Reflectivity, Rainfall Intensity	Regional, hourly data from NOAA's Doppler Radar sites at many CONUS locations. Spatial resolution is 1 km.	
Northern Hemisphere Extratropical Cyclone Tracks Data Base	NHECT	FLENUMMETOC DET Asheville	Central Pressure, Direction of Movement, Speed of Movement	Northern hemisphere from 1960 to 1993 with 1° resolution, updated annually. Replaces the paper climatic atlas 'Mariners Worldwide Climatic Guide to Tropical Storms at Sea.	
Pilot Balloon Observations	PIBAL	FLENUMMETOCCEN	Upper Level Atmospheric Observations	Global atmospheric point data from wind-tracking balloons retained up to 30 days.	

Precipitable Water		USAFETAC	Precipitable Water	Coverage of Northern Hemisphere, North of 20°N from 3/77 to present. Resolution of 65x65 polar stereograph, 206 nm at 60°.	
Radiosonde Observations	RAOBS	FLENUMMETOCCEN	Upper Air Temp., Winds, Humidity	Global point data taken at mandatory and significant reporting levels twice daily and retained up to 30 days.	
Real-Time Nephanalysis	RTNEPH	USAFETAC	Cloud Type, Percent Coverage, Min/Max Cloud Base, Total Cloud Coverage, Present Weather Report, Visibility	Global data available every synoptic hour. Spatial resolution is 512 x 512 polar stereographic, 26 nmi at 60°.	
Real-Time Nephanalysis-Low, Middle, High Type/Amount)	RTNEPH-LMHT/A	USAFETAC	Cloud Type and Amount (low,mid, high), Total Cloud Coverage	Worldwide coverage from 1/84 to present. Spatial resolution is 512 x 512 polar stereographic, 26 nmi at 60°.	
Low Level Satellite Wind Measurements	SATWINDS	FLENUMMETOCCEN	Winds	Wind data of approximately 1/8 of earth's surface from geosynchronous orbits from cloud-drift sensors on GOES,GMS, METEOSAT, and INSAT satellites. Spatial resolution is 2-5 km under satellite tracks, with updates every 30 min. Data retained up to 30 days.	
Surface Ship Observations	SHIP SYNOPTIC	FLENUMMETOCCEN	Wind Speed and Direction, Humidity, Sea-Level Pressure, T, Precipitation, Cloud Height, Sea Height, Swell	Global surface weather observations taken from ship stations retained up to 30 days.	
Snow/No Snow		USAFETAC	Presence of Snow and Ice	Coverage of parts of the Northern and Southern Hemispheres from 12/75 to present. Spatial resolution 513x513 polar stereograph, 26 nm at 60°, divided into boxes of 64x64 grid points.	
Trajectory Bulletins		USAFETAC	Temperature (850,700,500 mb), Gradient Temperature, Dew Point (850,700,500 mb), Cloud Cover (850,700,500 mb)	Northern Hemisphere coverage from 1/77 to present for 121 locations. 21 separate paths at 6,12,18,24,30, 36, and 48 hour forecasts.	
Tropopause		USAFETAC	Pressure at Tropopause, Height of Tropopause, Temperature at Tropopause	Worldwide coverage from 1/77 to present for Northern Hemisphere and tropical strip, and 4/81 to present for Southern Hemisphere.	
Upper-Air Windows		USAFETAC	Wind Component (u,v), D-Value, Temperature, Dew Point Depression, Surface Pressure, SWEAT Index	Coverage of Asia, Europe, North America from 1/77 to present. Resolution for North America: 37x39 window, for Asis and Europe: 35x41 window, 103 nm at 60°N.	
Vandenburg Tower		USAFETAC	Wind Direction, Wind Speed, Temperature, Pressure, Vertical Temperature Differential	Coverage north of 20°N and south of 20°S from 1/77 to present. Resolution 65x65 polar stereograph, 206 nm at 60°.	
Coupled Ocean Atmosphere Mesoscale Prediction System	COAMPS	NRL-MRY	Water Vapor, Rain, Ice Crystals, Snow	Non-hydrostatic, regional, atmospheric model, run in triple nested mode (i.e., 81,27,9 km). Spatial resolution is 5-9 km.	

Derived Atmospheric Fields	DAF	FLENUMMETOCCEN	Clear Air Turbulence, Contrail Probability, Fog, Frontal Analysis, Freezing Height, Rain Rate, Relative Humidity	Global forecasts to 60, 72, or 96 hours, updated on 12-hour cycle, with spatial resolution of 1°.	
High Resolution Winds	HRW	ARL	Temp., Winds, Vertical Velocity, Relative Humidity	Limited area model run for Camp Pendelton and Fort Hunter Ligget regions on a 10 x 10 km grid. Utilizes high resolution terrain data base with outputs at 10, 250, 500, and 1000 m. Spatial resolution is 200 m.	
Naval Operational Global Atmospheric Prediction System	NOGAPS	FLENUMMETOCCEN	Abs. Vort, Air Temp, Conv. Clouds, Conver. Precip., Diver.,Dew-Pt Depress,Geopot. Ht.,Ground Wetness,SST,Ice Cover,Lifting Conden. Level,IR Flux, Latent, Sens.,and Tot. Heat Fluxes,Snow Depth,Wind Dir/Speed/Stress,Sfc Press.,Solar Rad.,Cloud Cov.,Tot.Prec	Global, spatial resolution of 82 km. Forecast provided to 120 hours and distributed on a 12-hour cycle.	
Naval Operational Regional Atmospheric Positioning System	NORAPS	FLENUMMETOCCEN	Air Temp, Geopotential Height, Surface Pressure, Total Precip, Wind Dir/Speed, Absolute Vorticity, Conv. Precip, Latent, Sensible, and Total Heat Fluxes, Solar Radiation, Vapor Pressure	Atmospheric forecast (up to 48 hours) model that can be run for any user-specified are in the world. Current regions include CONUS, Europe, Indian Ocean, and Asia. Spatial resolution is currently 45 km.	